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ABSTRACT

Monitoring and subsequently simulating student transfer patterns from one academic major (or level) to another typically enables an institution to estimate future student enrollment distributions across academic areas. At the University of Missouri-Columbia (UMC), a student flow model not only simulates the patterns of student transfer but also enables academic units to monitor the "caliber" of students transferring across disciplines as well as those exiting the institution entirely. The model has been used at UMC to: (1) provide individual feedback reports to each academic dean illustrating the number and caliber (ability) of students which that academic unit "exchanges" with other academic units including the numbers of eventual distinguished graduates and dropouts "imported from" or "exported to" other academic units; (2) analyze the attrition rate, reentry rate, and caliber of students withdrawing from UMC semester by semester; (3) calculate the contribution of each academic unit to the aggregate campus attrition rate and simulate the expected attrition rate under alternative enrollment distributions of students across academic disciplines; (4) simulate the expected enrollment and academic transfer patterns by sex as compared with actual data in order to evaluate underrepresentation of females across academic disciplines (Title IX); and (5) provide data for student counseling regarding the average frequency of student transfer, the typical semester when the first change occurs, what type of student changes academic areas most often, and "transfer profiles" for eventual distinguished graduates vs. dropouts. (Author/LBH)

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S A I R

SIMULATING STUDENT FLOW:
Institutional Research Applications

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Abstract

Monitoring and subsequently simulating student transfer patterns from one academic major (or level) to another typically enables an institution to estimate future student enrollment distributions across academic areas. Such estimated enrollment for subsequent terms may then be used in conjunction with "Resource Requirement Prediction Models" (RRPM) to estimate future unit and total costs of instruction for each academic discipline. NCHEMS has generated software and support material to assist an institution with these projections. There are, however, many other significant pragmatic applications of student flow simulation.

At the University of Missouri-Columbia (UMC) a student flow model has been created which not only simulates the patterns of student transfer but also enables academic units to monitor the "caliber" of students transferring across disciplines as well as those exiting the institution entirely. The model has been used at UMC to: (1) provide individual feedback reports to each academic dean illustrating the number and caliber (ability) of students which that academic unit "exchanges" with other academic units including the numbers of eventual distinguished graduates and dropouts "imported from" or "exported to" other academic units, (2) analyze the attrition rate, reentry rate and caliber of students withdrawing from UMC semester by semester, (3) calculate the "contribution" of each academic unit to the aggregate campus attrition rate and simulate the expected attrition rate under alternative enrollment distributions of students across academic disciplines, (4) simulate the expected enrollment and academic transfer patterns by sex as compared with actual data in order to evaluate underrepresentation of females across academic disciplines (Title IX), and (5) provide data for student counseling regarding the average frequency of student transfer, the typical semester when the first change occurs, what type of student changes academic areas most often, and "transfer profiles" for eventual distinguished graduates vs. dropouts.

Student flow models typically have been constructed to chart and subsequently predict academic progress of students through the institution. Such models provide the tools for estimating the movement of students between various fields of study at various academic levels. Based upon historical data, these models describe expected transfer patterns from one academic major to another, consequently enabling the administrator to estimate the probabilities that such academic shifts will occur in the future.

Using the student flow model, the future enrollment patterns can be simulated. A series of matrices of "transitions probabilities" serve as the core of the model. These matrices provide the parameters necessary to estimate the chances that students will move (flow) from one major into another. Given any initial distribution of matriculating students across academic fields of study, the student flow model, utilizing these transition matrices, predicts the future semester by semester enrollment distributions of students across academic areas. Estimated student enrollment patterns may then be used in a variety of ways.

Estimated enrollment projections generated by the student flow model are frequently used in conjunction with "resource requirement prediction models." If enrollments by academic level and discipline can be estimated and if faculty teaching load is determined by discipline and academic level, then personnel costs (or total costs) of educating that entering distribution of enrolling students can be calculated. Resource Requirement Prediction Models (RRPM) use student flow models as input in order to estimate future unit and total costs of instruction for each academic discipline. NCHEMS has generated software and support manuals to assist institutions in constructing student flow models and linking these models to subsequent resource allocation models. Although very useful for programming planning and budgeting, there are, however, many other significant pragmatic applications of student flow simulation.

This paper will present examples of several other pragmatic applications of a student flow model developed and used at the University of Missouri-Columbia (UMC). The model developed at UMC was estimated from a longitudinal study of all full-time entering freshmen in 1969. Academic progress of this student cohort was monitored for five consecutive years (11 semesters). The data so constructed also contained ability levels, counseling center contact, and grade point averages for all students during this time period. Using this data, transition matrices were derived for ten semesters. The theoretical basis of the student flow model subsequently created from these matrices is presented in the technical appendix.

The University of Missouri-Columbia (UMC) student flow model has been created not only to simulate the patterns of student transfer but also to monitor the "caliber" of students transferring across disciplines as well as those exiting the institution entirely. The model has been used at UMC to:

(1) provide individual feedback reports to each academic dean illustrating the number and caliber (ability) of students which that academic unit "exchanges" with other academic units including the numbers of eventual distinguished graduates and dropouts "imported from" or "exported to" other academic units,

(2) analyze the attrition rate, reentry rate and caliber of students withdrawing from UMC semester by semester,

(3) calculate the "contribution" of each academic unit to the aggregate campus attrition rate and simulate the expected attrition rate under alternative enrollment distributions of students across academic disciplines,

(4) simulate the expected enrollment and academic transfer patterns by sex as compared with actual data in order to evaluate under-representation of females across academic disciplines (Title IX), and,

(5) provide data for student counseling regarding the average frequency of student transfer, the typical semester when the first change occurs, what type of student changes academic areas most often, and "transfer profiles" for eventual distinguished graduates vs. dropouts.

Analyzing "exchange of students" among academic units

Particularly in periods of declining enrollments it is essential for decision makers to assess what kinds of students are attending their campus and which disciplines they are pursuing. With data describing these students and their academic choices, the institution can determine faculty staffing patterns and expected output (graduates and dropouts) based upon input quality of students. Such data should illustrate the institution's competitive position in attracting and retaining various qualities of students in the academic marketplace. In a large university, deans of major academic units (eg. colleges, divisions) during periods of resource constraints often require data describing their competitive position among academic disciplines in order to (1) define their resource requirements, and (2) assess the "caliber" of students entering, choosing not to enter, or leaving their program. The student flow model at UMC was created to provide such data.

The first application of the UMC student flow model produced a series of individually tailored "interdivision transfer" reports illustrating the migration and "caliber" of students transferring from one academic unit to another. Each academic division was cast as either a "net importer" or a "net exporter" of students with other academic divisions. Using these profile reports the academic dean could examine the pattern and magnitude of the exchange of students with other divisions based upon actual data for each semester over five years.

In addition to classifying an academic division as either a net importer or net exporter of students in the aggregate, the profile reports also illustrated whether the academic division over the five-year span was an importer or exporter of (1) students who eventually graduated, or (2) students who subsequently failed to graduate from UMC. Table I illustrates such a presentation for the Arts and Science division.

	All Students	*Eventual Dropouts*	*Eventual Graduates*	*Eventual Distinguished Graduates*
A & S as a net importer	Engineering	Engineering	Engineering	
A & S as a net exporter	Agriculture B & PA Education Journalism Combined Program Home Economics Public & Community Services Nursing	Agriculture B & PA Education Journalism Home Economics	Agriculture B & PA Education Journalism Combined Program Home Economics Nursing	B & PA Education

Table I. Interdivisional import/export status of the College of Arts and Science (A & S).

The profile reports presented average ability levels for students in each of the three categories above. Serving as a proxy for "caliber" of students, average SCAT scores were calculated as an integral step in the student flow estimation procedure. For each matrix depicting the frequency of student transfer (one for each semester) a companion matrix of "caliber" of students transferring was generated. Each cell of the matrix represented the average SCAT level of those students exiting one division and entering another. Adding together data for all semesters then produced an aggregate student "migration matrix" and the companion student "ability matrix" (see Table II). It should also be noted that tables analogous to Table II were generated for each of the three categories of student (graduate, distinguished graduate, eventual dropout). For presentation in the individualized profile reports, however, only succinct statements based upon the tables were provided to each dean.

Analyzing attrition and reentry rates

The category labeled "none" in the Frequency of Student Transfer matrix (illustrated in Table II) contains the cumulative frequency of student withdrawal and subsequent reentry (if any) into the university. Tallying the column labeled "none" provides the cumulative attrition during a five year span. Summing the row total for the row labeled "none" provides the cumulate reentry during the same five year span. The student flow software generates analogous matrices for each semester over the five year period. Consequently the cumulative semester by semester attrition and reentry rates can be computed.

The attrition and reentry calculations over the five year period can be supplemented by a corresponding calculation of the ability levels of students leaving the university. Using the corresponding categories labeled "none" in the ability matrix (see Table II), average SCAT ability levels for exiting and reentering students (either aggregate or by specific academic division) provide substantial data reflecting (1) the caliber of students lost to attrition, and (2) semesters during a five year period when higher caliber students are expected to leave.

TOTAL MIGRATION FROM FALL'69 THROUGH WINTER'74

ALL STUDENTS

INTERDIVISION MIGRATION MATRIX (FREQUENCY)

DIVISION ENTERED

EXIT	AG	AGS	BPA	ED	ENGR	GRAD	JOUR	LAW	MED	COMB	VMED	FOR	HEC	SCS	NURS	NONE
AG		16	5	8	3	157	1	0	0	7	0	4	0	1	0	230
AGS	45		239	259	15	464	183	0	0	58	0	6	41	13	9	1152
BPA	1	2		3	0	228	0	2	0	2	0	0	0	0	0	60
ED	6	55	8		1	487	6	0	0	29	0	1	14	15	5	457
ENGR	16	80	9	16		93	0	0	0	14	0	8	1	1	0	148
GRAD	0	0	0	1	0		0	0	0	0	0	0	0	0	0	2
JOUR	0	4	0	2	0	170			0	2	0	0	0	0	0	27
LAW	0	0	0	0	0	2	0			0	0	0	0	0	0	0
MED	0	0	0	0	0	0	0	0		0	0	0	0	0	0	6
COMB	0	3	1	1	1	102	2	0	0		0	0	0	0	0	0
VMED	0	0	0	0	0	0	0	0	0	0		0	0	0	0	1
FOR	6	4	1	4	0	19	0	0	0	0	0		0	0	0	32
HEC	2	10	2	32	0	78	0	0	0	1	0	0		1	0	104
SCS	0	0	1	2	0	26	0	0	0	1	0	0	3		1	11
NURS	1	2	0	0	0	49	0	0	0	1	0	0	0	0		26
NONE	71	155	32	81	43	55	13	0	0	0	1	9	16	7	6	

INTERDIVISION MIGRATION MATRIX (AVERAGE APTITUDE)

DIVISION ENTERED

EXIT	AG	AGS	BPA	ED	ENGR	GRAD	JOUR	LAW	MED	COMB	VMED	FOR	HEC	SCS	NURS	NONE
AG		51.6	49.8	47.3	50.7	48.3	46.0	0.0	0.0	55.7	0.0	46.3	0.0	50.0	0.0	45.2
AGS	47.3		51.2	50.1	53.9	55.1	55.5	0.0	0.0	60.2	0.0	53.2	48.1	47.7	51.2	50.4
BPA	56.0	47.0		49.0	0.0	51.2	0.0	60.0	0.0	64.0	0.0	0.0	0.0	0.0	0.0	49.3
ED	41.3	49.8	46.5		52.0	48.7	48.1	0.0	0.0	52.1	0.0	50.0	46.5	44.2	52.6	45.1
ENGR	52.0	53.0	52.4	53.1		54.2	0.0	0.0	0.0	62.7	0.0	49.0	50.0	42.0	0.0	53.5
GRAD	0.0	0.0	0.0	49.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.5
JOUR	0.0	43.5	0.0	61.5	0.0	55.1		0.0	0.0	54.5	0.0	0.0	0.0	0.0	0.0	54.5
LAW	0.0	0.0	0.0	0.0	0.0	60.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MED	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
COMB	0.0	58.3	63.0	53.0	62.0	58.0	57.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	62.0
VMED	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	48.0
FOR	43.2	60.3	47.0	42.3	0.0	51.1	0.0	0.0	0.0	55.0	0.0		58.0	0.0	0.0	46.9
HEC	60.0	47.4	60.0	49.4	0.0	48.4	0.0	0.0	0.0	66.0	0.0	0.0		49.0	66.0	44.3
SCS	0.0	0.0	45.0	45.5	0.0	46.7	0.0	0.0	0.0	51.0	0.0	0.0	0.0		0.0	44.4
NURS	65.0	56.0	0.0	0.0	0.0	53.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		53.7
NONE	45.2	52.0	49.0	46.9	56.0	51.3	48.5	0.0	0.0	0.0	48.0	40.9	43.5	46.3	53.2	

Table II. Frequency and caliber of student interdivisional transfer.

Calculation and simulation of each academic division's contribution to total enrollment and attrition

The third pragmatic application of the student flow model enables the institution to examine enrollment and attrition from a structural rather than aggregate perspective. Although the institution has an aggregate attrition rate which accumulates semester by semester, some academic divisions may contribute more to that attrition rate than others. The matrices illustrated by Table II demonstrate the frequency of student transfer from any academic division into the category "none." When the historical data are analyzed using student flow software for only those students who subsequently failed to graduate, Table II provides the figures necessary to calculate each division's contribution to the aggregate attrition rate. The ability matrix in Table II similarly enables the institution to examine the caliber of students leaving the university who previously had been enrolled in each academic division.

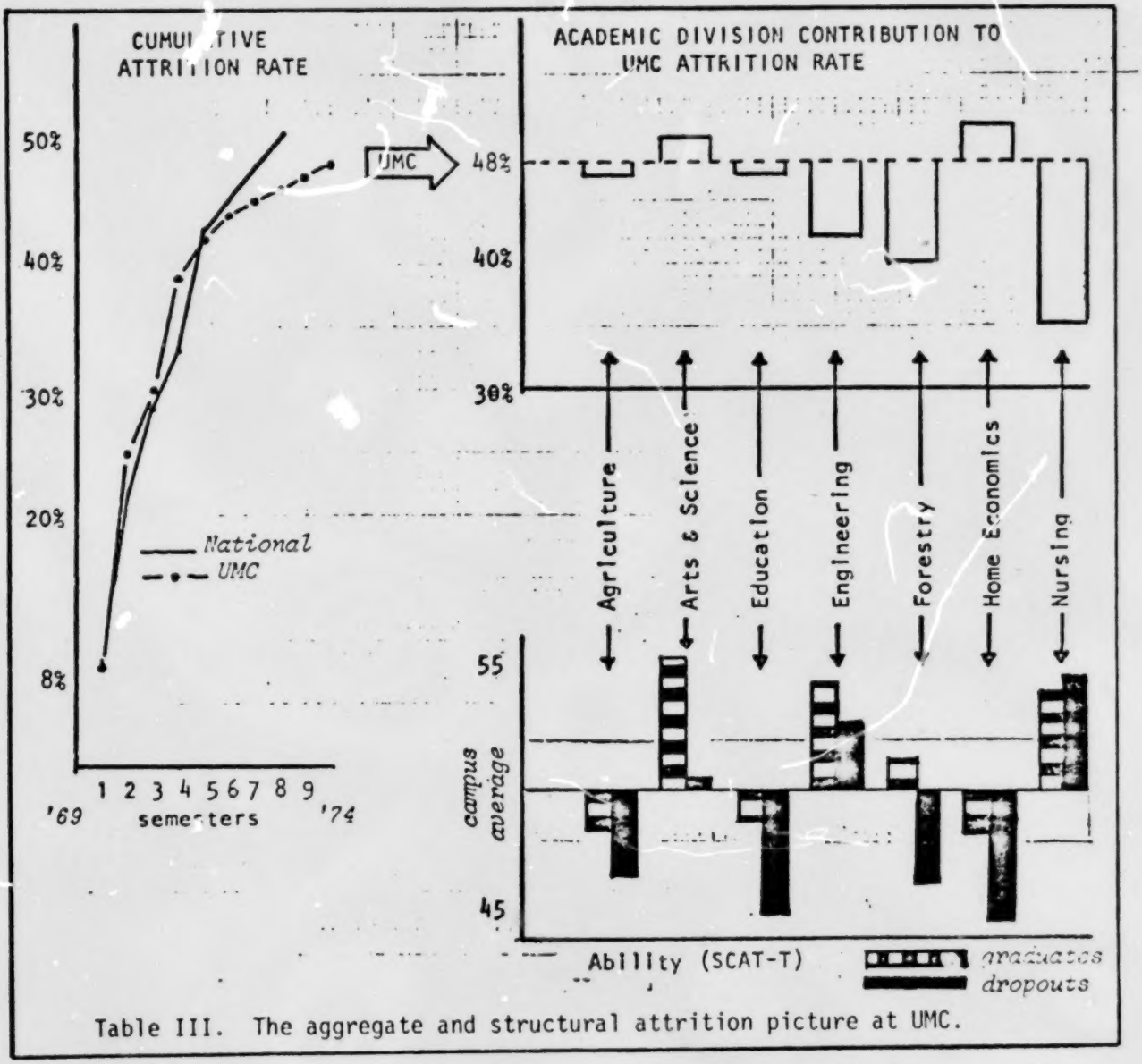

Table III. The aggregate and structural attrition picture at UMC.

Table III displays this data for UMC and conveys the following message: "Although the aggregate campus attrition rate is commensurate with national figures, not all UMC academic divisions contribute equally to the loss of students and not all those students who leave the various academic divisions are below average in their ability."

Data presented in Tables II and III have been extracted from the estimation process necessary to generate transition probabilities and parameters for student flow across disciplines. The UMC student flow software provides such descriptive data incidentally in the development of the simulation model. The student flow simulation enables one to simulate the expected transfer patterns and subsequent enrollment array of students across academic divisions for each of ten consecutive semesters. Once its parameters have been estimated from historical data, the model is driven by specifying an initial enrollment distribution. Selection of any initial enrollment distribution (across academic units) enables the user to examine (1) the subsequent "fanning out" or transfer of students across academic divisions over a five year period, and (2) the impact of that initial enrollment distribution on subsequent graduation and attrition rates. In addition to its utility for the campus, this model provides a unique application to each academic unit.

Any academic unit can examine the expected five year flow of those students who originally entered that particular academic division. To isolate the expected transfer pattern of only those students originally entering Arts and Science for example, the initial enrollment distribution which could be chosen for the model might look as follows:

Academic Division	Initial Enrollment Distribution
Agriculture (Ag)	0
Arts and Science (A & S)	100
Business (B & PA)	0
Education (Ed)	0
Engineering (Engr)	0
Journalism (Jour)	0
Law (Law)	0
Medicine (Med)	0
Combined Programs (Comb)	0
Veterinary Medicine (VMed)	0
Forestry (For)	0
Home Economics (HEc)	0
Social & Community Services (SEC)	0
Nursing (Nurs)	0

Such an initial enrollment distribution is of course fictitious, since it assumes that faculty and resources are available in all divisions but students only enter one division (Arts and Science). However, choosing such a distribution enables one to examine in a rudimentary fashion the progress of these students over ten semesters. Based upon the matrices of transition probabilities, the student flow model would return the following simulation (see Table IV).

	Academic Division															
Semester	Ag	A&S	BPA	Ed	Engr	Jour	Law	Med	Comb	VMed	For	HEC	SCS	Nurs	Grad	None
1	0	88	0	3	0	0	0	0	0	0	0	0	0	0	0	8
2	1	67	0	6	0	0	0	0	0	0	0	1	0	0	0	25
3	2	56	0	8	1	0	0	0	0	0	0	1	0	0	0	30
4	2	30	10	8	1	7	0	0	0	0	0	1	1	0	0	40
5	2	25	9	9	1	7	0	0	1	0	0	1	1	0	1	43
6	2	20	9	7	1	7	0	0	2	0	0	1	1	0	5	45
7	1	8	3	3	0	1	0	0	2	0	0	0	0	0	36	45
8	1	2	1	1	0	0	0	0	0	0	0	0	0	0	47	46
9	1	2	1	1	0	0	0	0	0	0	0	0	0	0	47	47
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52	48

Table IV. Simulated enrollment pattern for a hypothetical entering distribution composed entirely of Arts and Science students.

Since the model assumes exactly 100 students enter the Arts and Science division, inferences can be phrased equivalently in percentages. Based upon the model (estimated from data for the period 1969-1974), the following conclusions may be drawn from Table IV.

* During their first five years (ten semesters) some of the 100 Arts and Science students can be expected to migrate (transfer) to all other academic divisions except: law, medicine, veterinary medicine, and forestry.

* The business school and the College of Education attract more students from Arts and Science than do the other academic divisions. The business school begins to attract those students after two years, while the College of Education does so immediately.

* Of those students who originally enrolled in Arts and Science, 52% will eventually graduate from UMC in some division within ten semesters.

* 48% of those students entering Arts and Science originally will subsequently fail to graduate from UMC within five years. Eight percent will drop out by the end of the first semester and 40% will have left by the end of their second year.

Using an on-line interactive program, various initial distributions of students can be chosen to analyze the impact upon aggregate attrition and graduation rates. Other questions, for example, which such simulation can support include:

* What is the impact of a uniform entering enrollment distribution?

* What shifts in the distribution of entering students across disciplines will result in faster or slower graduation?

* Which divisions jointly improve the aggregate graduation rates and consequently reduce the aggregate attrition rates?

* Which academic programs attract students initially who drop out the quickest?

Clearly the stochastic simulation model is limited to the extent that it was constructed (estimated) based upon data in the past and programs and environments constantly change. However, the interactive simulation capability does provide at least rough insight instantaneously to an academic dean interested in examining his program's relationship with other units in the campus attrition and retention picture.

Simulation of expected enrollment and transfer patterns for special groups of students

The student flow simulation can also be used to analyze transfer patterns of special groups of students. Under this application the focus is upon a category of student rather than a particular discipline. For generalizability, the model was originally estimated using historical data on all students. The model was estimated based upon "people" data and illustrates the expected migration of any entering distribution of people regardless of their peculiar characteristics. It is therefore particularly useful as an unbiased baseline in simulating the expected enrollment patterns of such groups as minorities, women, handicapped, etc. Since parameters of the model were originally estimated irrespective of any characteristics of the group, the projected enrollment pattern predicted for females, for example, is sensitive only to the unique entering distribution of those females.

At UMC, this application of the model was employed in conjunction with campus self-evaluation efforts relative to Title IX. The initial hypothetical entering student distribution chosen for the simulation was the actual entering distribution of freshman females in 1969. The student flow simulation returned a table analogous to Table IV projecting the expected enrollment for those females in each academic division for each of ten semesters.

When compared to the data available on the actual enrollment of these females over five years, discrepancies were revealed between expected and actual female representation across the academic disciplines. In some fields interdivisional transfer had resulted in greater magnitudes of female enrollment than would be expected. In other fields actual female enrollment precipitated by interdivisional transfer was considerably lower than would be expected from that predicted by the transition matrices in the model. Consequently structural "pockets" of female underrepresentation in academic fields of study were identified. Of course, UMC has

changed since that model was originally estimated, eg. female enrollment patterns. New transition estimates would be necessary to ascertain similar conclusions for females, minorities, or any other special groups today.

Student flow data as "consumer information" for the student

A final application of the student flow model benefits the student directly. Bewildered by the size, feeling of isolation and lack of information in a major university, students quite often are unaware of the normal "change of major" phenomenon which the typical student experiences in the course of a college career. Student anxieties and self-doubt about the act of changing an academic program can be reduced by using the student flow model to document the magnitude and characteristics of the occurances of division transfer on a campus. Such information available to the student can precipitate informed decisions on career choice unencumbered by misperceived notions that "good students are absolutely certain of their career." In addition, unnecessary, premature, or late changes of major may be avoided if campus statistics describing the phenomena are publicly available and hopefully integrated with student advising activities on the campus.

The student flow software has generated the following charts and conclusions for the UMC campus (see Table V). In addition, migration matrices and corresponding ability level matrices have been produced for the eventual graduate, the eventual distinguished graduate, and the eventual dropout. Combined with research results from other studies of the UMC student, profiles for each category of student are available to supplement student advising.

* Although 52% of the students eventually graduated, only one in four graduated in the same division he entered.

* 75% of the students made at least one change either into another academic division or out of the University.

* 35% of the students made at least one interdivisional change (transfer) between Fall 1969 and Spring 1974.

FREQUENCY OF CHANGE FOR STUDENTS BY GROUP
(including interdivision transfer, exit and reentry)

	Non-Graduates	Graduates	Distinguished Graduates
no change	75%	48%	39%
1 change	11%	35%	51%
2 changes	11%	12%	8%
3 changes	2%	3%	2%
4 changes	1%	1%	0%

END OF THE SEMESTER WHEN FIRST CHANGE OCCURS

Semester	Non-Graduates	Graduates	Distinguished Graduates
1	19%	10%	17%
2	37%	17%	21%
3	13%	15%	30%
4	19%	40%	19%
5	4%	7%	2%
6	4%	4%	-
7	1%	4%	9%
8	2%	2%	2%
9	1%	1%	-

* Program changes are made by the most academically successful students. More distinguished graduates than graduates, and more graduates than non-graduates initiate academic program transfers.

* 86% of all initial changes are done by the end of the sophomore year.

* Distinguished graduates and non-graduates tend to make their initial change earlier than graduates. Most non-graduates decide, or are forced to exit the University early, and consequently make few program changes.

Table V. A profile of UMC student interdivisional transfer.

In Summary

In addition to its traditional use as input to resource requirement prediction models, models of student flow have other pragmatic applications. Many of these applications can serve a broad array of "clients." This paper has described various applications of the student flow software developed at UMC to support:

* The campus administration . . .to determine the attrition reentry, and graduation rates semester by semester, and the caliber of students involved in attrition vs. graduation.

* Institutional researchers . . .to calculate the contribution of each academic division to the campus attrition rate and to simulate the graduation and attrition rates under alternative entering student distributions.

* Campus federal compliance efforts . . .to simulate expected vs. actual female and/or minority enrollment and academic transfer patterns in order to identify potential pockets of under- or overrepresentation of certain target groups.

* Academic deans . . .to analyze the number and caliber of students their academic division imports from and exports to other academic divisions and the eventual disposition of those students exchanged (eg. graduates or distinguished graduates vs. dropouts).

* The UMC student . . .to recognize that most students do transfer between academic divisions early, frequently, and with success, particularly if such change is integrated with good academic advising and responsible career planning.

Certainly other applications may also be appropriate on a given campus or across campuses. For example, adapting the model to portray changes of major within a given academic division has potential for management within that college. At the other extreme, student transfer among institutions has statewide and national enrollment implications, both for resource management and marketing within the institutions, and for the consuming public particularly if data necessary to build the model are made available as consumer information to prospective students.

Technical Appendix

The methodology used to determine the expected student enrollment by division over time is described in D.J. Bartholomew's book entitled: Stochastic Models for Social Processes (Wiley, 1967, pp. 11-37.) The predictive model generated is based upon the theory of Markov Chains in discrete time. Time for purposes of the migration model will be 10 consecutive semesters. Essentially the model is composed of a sequence of transition probabilities (matrices) useful in projecting that a given initial distribution of students enrolled in m divisions will result in a given enrollment pattern across the m divisions after k semesters. More specifically:

Let N_k be an mx1 vector representing the distribution of students projected to be enrolled in the m divisions after time k, (k = 1, 10).

Let A_k be an mxm matrix composed of element a_{ij} representing the proportion of all students who exited division i and entered division j during semester k.

Let N_o be a vector (mX1) representing the initial distribution of students enrolled in the m divisions in Fall 1969.

Then,

$$N_1 = A_1' N_o$$

$$N_2 = A_2' N_1 = A_2' A_1' N_o$$

$$\vdots$$

$$N_k = \left(\prod_{j=1}^{k} A_j' \right) N_o$$

$$\vdots$$

$$N_{10} = \left(\prod_{j=1}^{10} A_j' \right) N_o$$

Let: $T_k = \left(\prod_{j=1}^{k} A_j' \right)$ Such that T_k will be referred to as the transition matrix for semester k.

then $N_k = T_k N_o$.

Consequently the predicted (expected) number of students enrolled in division i, $(n_i)_k$ after semester k (k = 1, 10) will be: $\sum_{j=1}^{m} (t_{ij})_k (n_j)_o$

The distribution of students enrolled across divisions after semester k will be the Vector $N_k = T_k N_o$.

SIMULATING STUDENT FLOW: INSTITUTIONAL RESEARCH APPLICATIONS

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Monitoring and subsequently simulating student transfer patterns from one academic major (or level) to another typically enables an institution to estimate future student enrollment distributions across academic areas. Such estimated enrollment for subsequent terms may then be used in conjunction with "Resource Requirement Prediction Models" (RRPM) to estimate future unit and total costs of instruction for each academic discipline. NCHEMS has generated software and support material to assist an institution with these projections. There are, however, many other significant pragmatic applications of student flow simulation.

At the University of Missouri-Columbia (UMC) a student flow model has been created which not only simulates the patterns of student transfer but also enables academic units to monitor the "caliber" of students transferring across disciplines as well as those exiting the institution entirely. The model has been used at UMC to: (1) provide individual feedback reports to each academic dean illustrating the number and caliber (ability) of students which that academic unit "exchanges" with other academic units including the numbers of eventual distinguished graduates and dropouts "imported from" or "exported to" other academic units, (2) analyze the attrition rate, reentry rate and caliber of students withdrawing from UMC semester by semester, (3) calculate the "contribution" of each academic unit to the aggregate campus attrition rate and simulate the expected attrition rate under alternative enrollment distributions of students across academic disciplines, (4) simulate the expected enrollment and academic transfer patterns by sex as compared with actual data in order to evaluate underrepresentation of females across academic disciplines (Title IX), and (5) provide data for student counseling regarding the average frequency of student transfer, the typical semester when the first change occurs, what type of student changes academic areas most often, and "transfer profiles" for eventual distinguished graduates vs dropouts.

The student flow model, its use at UMC, and other applications of the model in assessing the impact of institutional programs or the impact of institutional change will be presented in this paper.